

Trans Forum

News From Argonne's Transportation Technology R&D Center



Page 2

VIEWPOINT

Vehicle Competitions Test Student Ingenuity

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Page 4

RESEARCH REVIEW

SMARTE Truckers Take a New Approach to Cab Comfort

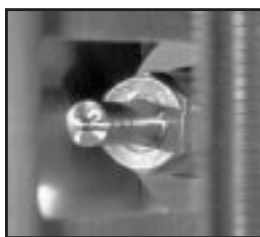
DOE program aims at saving fuel and maintenance costs while reducing emissions

For many long-haul truck drivers, today's modern rigs offer drivers air-conditioned and heated accommodations, all powered by their idling diesel engines. Argonne researchers recently showed that this power comes at a steep price — over \$1,800 a year per truck in added fuel and engine maintenance costs. The good news is that most engine idling costs and pollution can be avoided. *Page 4*

Argonne Turns a Bright Light on Diesel

Argonne researchers are using high-brilliance x-rays to probe diesel fuel sprays

Transportation industry professionals know that today's diesel engines are the most fuel efficient internal-combustion devices in existence — and, thanks in part to diesel spray research taking place at Argonne's Advanced Photon Source, tomorrow's will be even better. *Page 5*



Page 5

Sensing the Unknown

Real-time sensors for intelligent control of automotive systems

Think your car is mysterious and sophisticated now? Well, down the road your car's inner life will become even more complex, as it self-regulates with advanced sensor/actuating devices. Sensor/actuators such as those being explored by Argonne researchers are one way carmakers hope to produce "greener" and more fuel efficient cars in response to government/industry's Partnership for a New Generation of Vehicles program. *Page 6*

LOOKING DOWN THE ROAD *Page 7*

FASTRAX *Page 7*

PARTNERING WITH ARGONNE *Page 8*



Vehicle Competitions Test Student Ingenuity

To DOE's Shelley Launey, the results are "dramatic testimony to the promise of alternative-fuel vehicles"

Staff from the Center for Transportation Research at Argonne recently finished two major advanced vehicle engineering competitions in which student teams from 27 top engineering schools took part. The U.S. Department of Energy (DOE), General Motors, and about 30 other industry and government sponsors believe the technical advances that the students introduce to these Argonne-run competitions can help identify new ways to improve fuel efficiency and increase the use of domestic renewable fuels.

But the biggest payoff, believes Shelley Launey, manager of DOE's vehicle competitions and director of the DOE Clean Cities Program, is a new generation of talented, resourceful engineers who will graduate from college experienced in designing and building cleaner, safer, more economical cars and trucks.

The second annual Ethanol Vehicle Challenge, held May 19–26 at General Motors' Milford Proving Ground, challenged students to convert full-sized pickup trucks to run on E85, a fuel blend containing 85% corn-based ethanol. Increased technical support from GM for this year's competition allowed the students to recalibrate the stock powertrain control module to reflect the differences between gasoline and ethanol.

Three-quarters of the E85-converted trucks exceeded the fuel economy of the stock gasoline-powered truck, more than

one-third met or exceeded EPA's Low Emissions Vehicle standards, and all outperformed the stock truck in the acceleration and hill-climb events. "The results showed that E85 can perform as well as or better than gasoline in every way," Launey said.

The fourth and final FutureCar Challenge, held June 2–10, tested the students' ingenuity at redesigning popular consumer sedans to reach the same Partnership for a New Generation of Vehicles-driven goals that the auto industry is striving to achieve: double to triple fuel economy, reduced emissions, and no loss of consumer acceptability.

Each FutureCar team designed a six-passenger hybrid electric vehicle with a unique combination of powertrain control system, fuel, exhaust system, and vehicle weight reduction innovations. The winner, the University of Wisconsin-Madison, averaged 62.7 mpg in over-the-road fuel efficiency — 148% better than its gasoline counterpart — with a hybrid diesel/electric powertrain and aluminum engine cradle. "They had a great strategy in lightweighting," Launey said. "They redesigned and built 26 components from aluminum. They also acquired a new super-efficient diesel engine from Europe."

Another pioneering team, from Virginia Tech, not only successfully demonstrated a fuel cell vehicle for one of the first times in the United States, but also took second place overall and scored first in emissions. "The DOE fuel cell experts were awed by Virginia Tech's efforts," Launey said. "Their performance is especially impressive because they worked less than two years on their fuel cell car. FutureCar participants don't have the option of postponing the debut of their vehicles if they are not ready."

Next year the FutureCar Challenge will become "FutureTruck 2000," reflecting current trends and consumer tastes in sport utility vehicles and bringing a new set of challenges for our nation's future automotive engineers.



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For the 1999 Ethanol Vehicle Challenge, students from the University of Illinois at Chicago fitted their winning truck, "Ethyl," with an extra air intake system to take advantage of ethanol's ability to burn cleanly, and they installed a new fuel system made of dense plastic and stainless steel.

**Ethanol Vehicle Challenge Teams**

Cedarville College, Ohio
Crowder College, Missouri
Idaho State University
Illinois Institute of Technology
Kettering University, Michigan
Minnesota State University — Mankato
University of California, Riverside
University of Illinois at Chicago
University of Kansas
University of Nebraska — Lincoln
University of Texas at Austin
University of Texas at El Paso
University of Waterloo, Ontario
Wayne State University, Michigan

FutureCar Teams

Concordia University, Quebec
Lawrence Technological University, Michigan
Michigan Technological University
Ohio State University
Texas Tech University
University of California, Davis
University of Illinois — Urbana
University of Maryland
University of Michigan
University of Tennessee
University of Wisconsin — Madison
Virginia Tech
West Virginia University

**1999 Ethanol Vehicle Challenge Highlights**

Students convert full-size pickup trucks to run on E85 fuel

Better Fuel Economy

Three-quarters of the E85-converted trucks outperformed the stock gasoline-powered truck in fuel economy. The University of Illinois at Chicago improved fuel economy by more than 10% — especially impressive because ethanol has lower potential energy than gasoline.

Lower Emissions

More than one-third of the converted trucks met or exceeded EPA's Low Emissions Vehicle standard when running on E85. Three teams were within 0.020 g of meeting the Ultralow Emissions Vehicle standard for hydrocarbon emissions — quite an accomplishment for a car, much less a 4 x 4 truck.

More Power

All of the E85 trucks outperformed the stock gasoline-powered truck in the acceleration and hill-climb events.

DOE Secretary Richardson and more than 20 members of Congress participated in the FutureCar final-day activities.

**1999 FutureCar Challenge Highlights**

Students reengineer family sedans to achieve up to 80 mpg and reduce emissions but maintain safety, comfort, and affordability.

Lightweight Diesel/Electric Hybrid Gets Best Fuel Economy

The University of Wisconsin-Madison's vehicle, an aluminum-intensive Mercury Sable, averaged 62.7 mpg in over-the-road fuel efficiency — 148% better than its gasoline counterpart — placing first overall with a hybrid diesel/electric powertrain and aluminum engine cradle. The finished vehicle weighed 500 pounds less than its conventional counterpart.

Fuel Cell Vehicle Prevails in Emissions

The car placing second overall, a Chevrolet Lumina converted by Virginia Tech, was powered by a fuel cell and batteries, in one of the first demonstrations of a U.S. passenger car using this technology. As expected, this vehicle placed first in emissions.

Students' Invention Patented

The University of Illinois's design included a device the students invented to prolong the lives of two connected batteries by equalizing the rates at which they charge and discharge. The school patented the new device.



SMARTE Truckers Take a New Approach to Cab Comfort

DOE program aims at saving fuel and maintenance costs while reducing emissions

For many long-haul truck drivers, today's modern rigs are not only their workplace, but also a hotel room on wheels. Spacious sleeper cabs offer drivers air-conditioned and heated accommodations, all powered by their idling diesel engines. However, in a recent study, Argonne researchers showed that this power comes at a steep price — over \$1,800 a year per truck in added fuel and engine maintenance costs. Engine idling also takes its toll on the environment — parked trucks annually emit an estimated 6.5 million tons of carbon dioxide, 35,000 tons of nitrogen oxides, and 60,000 tons of carbon monoxide.

The good news is that most engine idling costs and pollution can be avoided. The U.S. Department of Energy's (DOE's) Office of Heavy Vehicle Technologies (OHVT) has initiated a program designed to reduce the unnecessary and costly idling of heavy truck diesel engines. The idling initiative is part of a larger OHVT program called SMARTE (Save Money and Reduce Truck Emissions).

"Some truck drivers seem to think that our efforts are designed to make them suffer in unheated or uncooled cabs. That is not at all our intent," explains Sid Diamond, who heads OHVT's Vehicle System Technologies group. "Our goal is to show drivers that they really don't need a 600-horsepower diesel engine to run their trucks' climate control units and appliances. Today there are a number of options that provide more energy efficient, cost-effective, and environmentally friendly solutions to control cab comfort and safety." These options include direct-fired burners for cab and engine heating, thermal storage units for cab heating and cooling, on-board auxiliary power supplies, and electrical power supplied at truck stops. These alternatives, which typically consume 80-90% less fuel than a diesel engine, significantly reduce both fuel and engine maintenance costs. The payback period can be as short as one year.

Diamond describes one such device, a 15,000-Btu auxiliary heater for truck cabs that consumes just a pint of diesel fuel per hour, compared to the gallon per hour consumed by most diesel truck engines. He adds, "Our calculations have shown



Thermal storage units like this one can provide inexpensive cab cooling and heating, helping to reduce truck engine idling.



Diesel engine idling costs truck owners over \$1,800 a year per truck in added fuel and maintenance costs.

that eliminating truck idling can save our nation an estimated 450 million gallons of diesel fuel each year — about 0.5% of all the petroleum used annually for surface transportation in the United States."

One reason truck operators have been reluctant to use auxiliary heating, cooling, and power units is the cost, which can run about \$3,000 for a typical model. Yet Argonne transportation analysts have shown that the annual savings quickly offsets the initial cost of auxiliary equipment. Their analyses assumed that the average heavy-duty freight-hauling (Class 8) truck averages 6 hours of idling a day and 43 weeks of use per year. This amounts to about 1,830 hours of engine idling annually — a low estimate compared to some reports. If auxiliary devices replaced idling for 1,450 of those hours (a conservative estimate) and used 85% less fuel, operators would save 1,230 gallons of fuel, or \$1,537 (at \$1.25 per gallon). Less engine wear would also significantly decrease the cost for preventive maintenance and overhauls, adding over \$275 in estimated annual savings.

Because the initial cost of the auxiliary devices may prevent their wider use in the industry, government officials are considering low-cost loans, potential tax benefits, and/or equipment weight waivers for operators who install and use the devices on their rigs.

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Argonne Turns a Bright Light on Diesel

Argonne researchers are using high-brilliance x-rays to probe diesel fuel sprays

The public's perceptions often lag behind the rapid pace of technological change. Ask most people about diesel technology, and they picture 18 wheelers and buses spewing out clouds of smelly, sooty exhaust. In contrast, transportation industry professionals know that today's diesel engines are the most fuel-efficient internal-combustion devices in existence — and, thanks in part to diesel spray research taking place at Argonne's Advanced Photon Source (APS), tomorrow's will be even better.

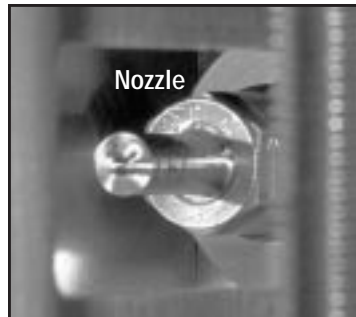
Modern diesel engines emit 28% less carbon dioxide — the principal greenhouse gas — and get 30% better fuel efficiency over the total energy cycle than do comparable gasoline-fueled engines. Because improved fuel efficiency helps conserve petroleum resources, greater reliance on diesel technology could reduce our dependence on foreign oil sources. But if diesel-fueled passenger cars are to compete with the gasoline Goliath, they must become still cleaner and more efficient.



Diesel spray research team (left to right): Armon McPherson, Jin Wang, Chris Powell (XFD), and Sreenath Gupta, Sherman Smith, and Ramesh Poola (ESD).

"To transcend emission problems, high-speed diesel engines will have to use new fueling technologies," says Sreenath Gupta, an engineer at Argonne, "in particular, fuel spray characteristics must be improved." Gupta and Argonne physicist Jin Wang have achieved unprecedented success with an innovative approach to studying fuel-injection systems for diesel engines. On the basis of initial results, they have reported — for the first time ever — detailed *quantitative* data on what takes place within the optically dense liquid core of the diesel fuel spray, where conventional means are inadequate to reveal what is happening.

Using synchrotron x-ray beams from Argonne's Advanced Photon Source — which is optimized for production of high-brilliance x-rays — they obtain high-resolution "snapshots" of fuel spray phenomena over times measured in



The diesel spray nozzle is at the heart of Argonne's state-of-the-art experimental setup for obtaining quantitative data on optically dense diesel sprays.

nanoseconds. The experimental setup — a high-pressure, common-rail fuel-injection system like that employed in diesel cars, modified for x-ray absorption measurements — uses one of the APS's bending-magnet beamlines. By means of x-ray absorption techniques (to be supplemented by x-ray fluorescence and small-angle x-ray scattering), the researchers can

- Get accurate, quantitative information throughout the spray region.
- Study the mechanisms of spray breakup and atomization in detail.
- Investigate the effects of nozzle geometries (both near and far from the nozzle) and injection parameters on spray characteristics.

Quantitative fuel spray data are needed in order for engineers to design injection system components that will achieve higher fuel efficiency and lower emissions. Physical properties like droplet size and density, mass flux and spatial distribution, air-to-fuel ratio, and velocity of spray particles govern the spray's combustion behavior, which in turn determines the efficiency and emissions levels. Neither optical techniques (such as laser interferometry) nor non-optical approaches (droplet collection, use of probes) can measure such properties deep inside the spray; the Argonne researchers, however, have shown that their x-ray techniques can.

The Argonne team hopes to identify the most critical injection parameters and to test prototype nozzle/injection systems on a direct-injection diesel engine. Argonne's research is equally applicable to both gasoline and diesel fuel sprays. Research supported by DOE's Office of Advanced Automotive Technologies on spray structures in direct-injection gasoline-fueled engines for passenger cars is now under way. This cross-cutting research should also benefit diesel truck engines.

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Sensing the Unknown

Real-time sensors for intelligent control of automotive systems

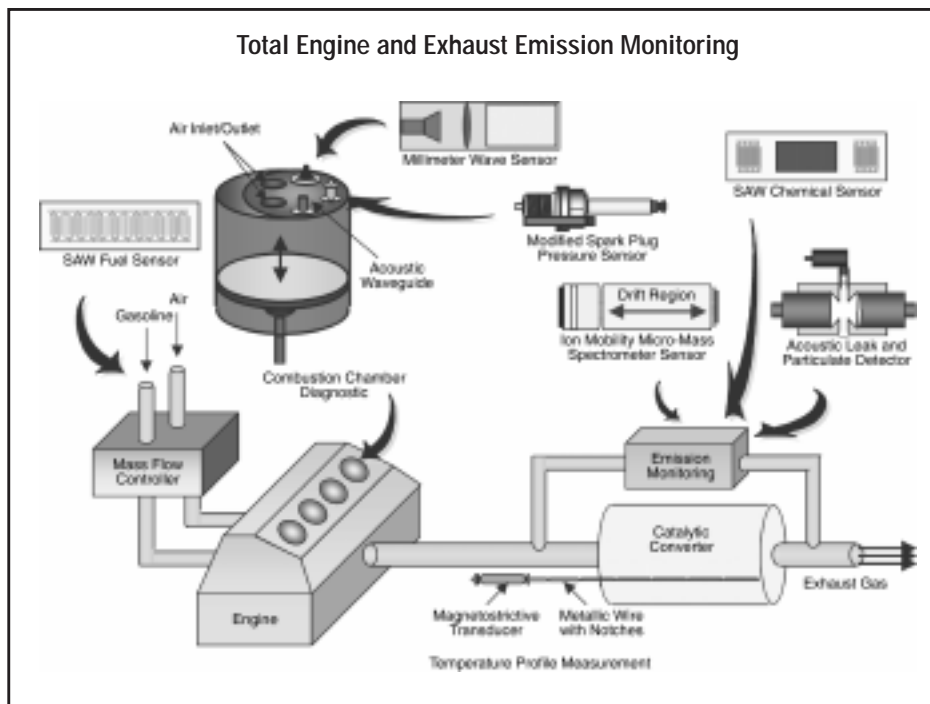
Think your car is mysterious and sophisticated now? Well, down the road your car's inner life will become even more complex, as it self-regulates with advanced sensor/actuating devices. Sensor/actuators such as those being explored by Argonne researchers are one way carmakers hope to produce "greener" and more fuel efficient cars in response to government/industry's Partnership for a New Generation of Vehicles program.

Scientists at Argonne are researching an array of sensors that record vehicle information instantaneously, so that engine and drivetrain components can be activated or adjusted in response. The result will be constant, seamless adaptation of system components to each other as the car travels, delivering better mileage and fewer emissions.

To optimize combustion, on-board, real-time sensor/actuators can measure in-cylinder pressure and temperature, oil film thickness and quality, catalytic converter temperature, and other parameters, and then regulate the engine's fuel/air ratio accordingly. Advanced sensor/actuators can also analyze engine emissions and adjust catalyst mixing in response.

Argonne's automotive sensor research has so far focused on on-board diagnostics of the catalytic converter. Such diagnostics are used in our cars now, but the work of current sensors is slow (2-3 minutes), and there is no feedback loop for self-regulation. The present-day sensors simply report on system performance, perhaps warning the operator when the vehicle is out of compliance.

In partnership with the Big Three automakers, Argonne is researching four technologies for monitoring carbon monoxide, nitrogen oxides, and particulate emissions: microwave/millimeter-wave spectroscopy, surface acoustic wave microsensors, ion mobility sensors, and ultrasound particulate monitors. In the near future, the actuator phase of the project will bring intelligent control of automotive engines and processes closer to fruition.



Several other promising automotive sensor/ actuator technologies have been conceived at Argonne:

- In-cylinder sensors — piezoelectric, ultrasonic, and microwave cavity pressure sensors; microwave and ultrasonic oil quality monitors; millimeter-wave proximity sensors.
- Air/fuel control systems — surface acoustic wave resonator air/fuel sensors, smart material valves.
- Emissions control systems — ultrasonic and microwave smoke sensors in the tailpipe, acoustic temperature sensors and shape memory alloy actuators in the catalytic converter.

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Well, we have had a busy spring and summer in the Transportation Technology R&D Center. On May 1, Argonne held an open house to allow the public to see what kind of research is going on at the Lab. We were fortunate to have four of our industrial research partners join in our open house festivities: the United States Council for Automotive Research, Ford Motor Company, General Motors Corporation, and John Deere and Company. Displays included Ford's direct-injection, aluminum, through-bolt assembly (DIATA) engine; a John Deere diesel engine; a General Motors EV-1 electric car; University of Illinois at Chicago's award-winning 1998 Ethanol Vehicle Challenge vehicle; and alternative-fuel vehicles from Argonne's test fleet.

May and June kept many of us busy with DOE-sponsored advanced vehicle competitions: the Ethanol Vehicle Challenge was held May 19–26 at GM's Milford Proving Ground, and the FutureCar Challenge — the nation's premier college-level automotive engineering competition — took place June 1–10 in Auburn Hills, Michigan. Those who follow these competitions are always impressed by what the students can accomplish on a very tight schedule. But this year, the teams surprised their sponsors, the press, and even themselves with how well they did (see story on page 2). They certainly impressed us.

Also in June, we were privileged to host the Secretary of Energy Advisory Board Meeting here at the Lab. The meeting was highlighted by a tour of our transportation research facilities, including the Advanced Powertrain and the Engine Research facilities. In July, we hosted the DOE Office of Transportation Technologies' Diesel Engine Combustion and Aftertreatment Review, which included over 30 presentations by laboratory and private researchers and also featured a tour of the TTRDC facilities. Both tours prompted some interesting questions and discussion.



FASTRAX

Two Argonne inventions have won R&D 100 awards, given annually by *R&D Magazine* to the 100 most significant technical products of the year. One of these, a device to improve the efficiency and performance of diesel engines, was invented by **Ramesh Poola** and **Raj Sekar** of Argonne's Energy Systems Division. The technique controls fuel and oxygen levels in diesel engines, reduces particulate and nitrogen oxide emissions, and increases power.

Christopher Saricks, of Argonne's Energy Systems Division, received a letter of appreciation from the National Research Council for his dedication during his term of service on the Committee on Ozone-Forming Potential of Reformulated Gasoline. Bruce Alberts, Chairman of the Council, expressed

TTRDC is proud once again this year to count two of our staff among the elite group of R&D 100 Award winners (see Fast Trax). The announcement came in July that Ramesh Poola (left) and Raj Sekar (right) will receive this prestigious award for their clean diesel technology, which can help clean our air while increasing fuel efficiency and improving engine performance.



We have also been participating this summer in DOE's anti-idling or SMARTE (Save Money and Reduce Truck Emissions) campaign (see story on page 4). This effort aims to reduce diesel truck idling, which would save truckers about \$1,800 per truck per year in fuel and increased maintenance costs and prevent emission of an estimated 6.5 million tons of carbon dioxide, 35,000 tons of nitrogen oxides, and 60,000 tons of carbon monoxide.



Remember, information about these and other Argonne efforts and events is available by contacting the individual whose name is listed at the end of the article or by visiting our increasingly popular web site.

Larry

Larry R. Johnson
Director

gratitude to Saricks and other volunteer scientists who have "given of their time to conduct programs and studies of importance to the nation."

Argonne's Energy Systems Division has one member with a silver tongue. For two years in a row, **Steve Plotkin** has received an award for "Outstanding Oral Presentation" at the Society of Automotive Engineers government/industry meeting. This year's meeting, titled "Kyoto Goals and Autos: an International Perspective," was held on April 28 in Washington, D.C., to discuss the characteristics and problems of the major world automobile markets in light of the global need to reduce greenhouse gases.



Argonne is seeking industrial partners to develop advanced transportation technologies. The following types of working arrangements can be made:

- In a *reimbursable R&D agreement*, Argonne's industrial partner pays the full cost of the research performed. The company generally takes title to any inventions, and proprietary information and research results are kept confidential.
- In a *cost-shared R&D agreement*, Argonne and its industrial partner share the costs of research. The company may obtain rights to intellectual property developed by Argonne. Proprietary information is kept confidential, and research results may be protected from disclosure for up to five years.

■ *Licenses* for Argonne inventions and software may be granted to companies that wish to develop them into marketable products or processes. Licenses may also be part of other agreements.

■ *Personnel exchanges* and *technical assistance* projects can be arranged with Argonne for short-term or rapid-turnaround work.

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